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# Memoirs of the Department of Agriculture in India

## THE INHERITANCE OF CHARACTERS IN RICE, II

BY

F. R. PARNELL, M. A., AG. DIP. (Cantab.)
*Government Economic Botanist, Madras*

WITH THE ASSISTANCE OF

G. N. RANGASWAMI AYYANGAR, B.A
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*Assistants in Economic Botany*

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NOTE.

*Coloured Plates.*

The original paintings are very imperfectly reproduced in the coloured plates. The latter, however, though not strictly accurate, will give some idea of the characters described.

F. R. P.

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[Received for publication on 20th July, 1921.]

## Introduction.

THIS is a continuation of a previous paper on the same subject, Part I [1], which contained earlier results on some of the same characters as are dealt with here. A certain amount of repetition occurs, especially where a modification of the previous presentation is necessary, but this has been avoided as far as possible by references to Part I.

It would be better, if possible, to make each part more complete in itself The work on inheritance, however, as at present carried on, is bound up with, and subsidiary to, the breeding of improved strains. It is frequently impossible, therefore, immediately to follow up and finish off points of interest as they arise; moreover it is often uncertain as to when they will be taken up again. In the circumstances it has been decided to publish any definite results as they become available without waiting for a degree of completion that may never be possible.

## Characters investigated.

1. GOLDEN COLOURING OF INNER GLUMES WITH MODIFYING FACTORS.

Some earlier results in connexion with these characters were given in Part I, pp. 80–86. The factors concerned have now been worked out in greater detail, though there are still certain points on which evidence is wanting.

[1] Parnell, F. R., and others. *Mem. Dept. Agri. India, Bot. Series*, IX, no. 2, Nov. 1917.

Four factors have been identified with certainty and one more, *E*, is put down provisionally. Adopting the 'presence and absence' notation, their description is as follows :—

*G* produces *dark gold*.

*I* modifies all golden colouring to a corresponding degree of *dark furrows* and inhibits golden colouring of the internode.

*P* produces a *piebald* pattern on dark gold or dark furrows.

*T* gives *tipped gold* from dark gold, *ripening straw* from ripening gold and *granular dark furrows* of degrees.

*E* regarded, provisionally, as giving *even-colouring* by prevention of *mottling*.

In the absence of *G*, and apart from other complications, the inner glumes are *ripening gold*. This colouration is quite distinctive, the glumes being almost green at flowering and passing through lemon yellow to a dull light gold at maturity (Plates I and II, fig. 1), unset grains remaining green. No case of the absence of this colouring, other than through inhibition, has been recorded, hence its production is not assigned to any factor in the notation employed.

A *golden yellow internode* is present in all plants with golden glumes, as also in the ripening straw type where ripening gold is inhibited by *T*. In other words, it occurs in all plants in the absence of *I*.

*The factor* G.

In the absence of *I* this factor produces a *dark gold* colouring of the inner glumes. The latter are definitely gold at flowering and darken as the grain develops to a reddish brown at maturity (Plate I, fig. 2, and Plate II, fig. 4). In unset grains the glumes do not darken appreciably with age.

In the presence of *I* all trace of gold disappears and it is replaced by a blackish brown pigment, showing mainly in the furrows of the glumes, giving the type described as *dark furrows* (Plates I and II, fig. 5). From the results of a large number of crosses it appears that *dark furrows* and *dark gold* are produced by the same factor, *G*, and that the presence or absence of *I* determines which colour shall develop.

A similar modification takes place in the case of *ripening gold* which, in the presence of *I*, is replaced by a very dilute form of dark furrows described as *ripening furrows* (Plate I, fig. 4, and Plate II, fig. 2). Thus *G* may be simply an intensifying factor which darkens the *ripening* gold and furrows types.

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1

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1. Ripening gold: 2. Dark gold: 3. Ripening straw: 4. Ripening furrows: 5. Dark furrows.

6 Pumpkin yellow
7 Crimson & yellow
8 Pippin gold
9 Pitch & gold
10 Orange fine &

*Dark gold, G G i i, × ripening gold, g g i i*, gives an $F_1$ rather lighter than the dark gold parent. In $F_2$ an ordinary *3 : 1* ratio of *dark gold : ripening gold* is obtained, as shown by the figures given below. The ripening golds are easily separable with absolute certainty. In the dark golds two groups can be distinguished since the heterozygotes are rather lighter in colour than the pure dark golds. A strictly accurate separation is not possible, however, as shown by the fact that of 112 plants described as dark 13 proved heterozygous, and of 117 medium 2 bred true.

Table I gives figures for a number of families in which this separation was made and shows a near approximation to the expected *1 : 2 : 1* ratio.

TABLE I.

*Segregation of* G g i i.

| Origin of parent | Ref. No. | Dark gold G G i i | Medium gold G g i i | Ripening gold g g i i |
|---|---|---|---|---|
| Medium golds from No. 1247 N .. | 1793 N | 231 | 440 | 206 |
| | 1797 N | 176 | 409 | 195 |
| | 1798 N | 181 | 411 | 176 |
| | 1799 N | 180 | 407 | 198 |
| | 1800 N | 218 | 463 | 232 |
| Miscellaneous .. | 8 lots | 1,658 | 3,372 | 1,674 |
| TOTAL .. | | 2,644 | 5,502 | 2,681 |
| * *Calculated 1 : 2 : 1* .. | | *2,707* : | *5,413* : | *2,707* |

* N.B. *All calculated ratios are given to the nearest whole number to avoid fractions.*

The following total figures were obtained by combining the families of Table I with others in which only the two main groups were separated :—

| | Dark gold G i | Ripening gold g i |
|---|---|---|
| 29 families .. .. | 16,104 | 5,483 |
| *Calculated 3 : 1* .. | *16,190* : | *5,397* |

Entirely similar results are given in the segregation of the type *G g II* where dark furrows replace gold. Here again three types can be distinguished in $F_2$, though in this case there is some uncertainty in separating the recessive group of ripening furrows from the medium furrows. Thus of 21 plants assigned to the former group 1 proved heterozygous, whereas of 26 noted as medium 2 bred true to ripening furrows.

The results of a number of families in which three groups were separated are given in Table II, which shows a *1 : 2 : 1* ratio.

TABLE II.

*Segregation of* G g I I.

| Origin of parent | Ref. No. | Dark furrows G G I I | Medium furrows G g I I | Ripening furrows g g I I |
|---|---|---|---|---|
| Cross No. 1236 N .. | 1760 N | 288 | 568 | 254 |
| Medium furrows from No. 1760 N .. | 2221 N | 91 | 180 | 105 |
| | 2222 N | 72 | 175 | 67 |
| | 2223 N | 67 | 117 | 64 |
| | 2225 N | 99 | 219 | 129 |
| | 2226 N | 144 | 310 | 151 |
| | 2229 N | 79 | 148 | 81 |
| | 2230 N | 67 | 148 | 72 |
| Miscellaneous .. | 4 lots | 409 | 839 | 428 |
| TOTAL .. | | 1,316 | 2,704 | 1,351 |
| *Calculated 1 : 2 : 1* .. | | *1,348* | *2,685* | *1,343* |

The total figures for all families showing this segregation, two groups only being separated, are as follows :—

| | Dark furrows G I | Ripening furrows g I |
|---|---|---|
| 23 families .. .. | 9,538 | 3,243 |
| *Calculated 3 : 1* .. | *9,586* | *3,195* |

### *The factor* I.

As already noted the presence of *I* changes any form of golden colouring of the inner glumes to a corresponding degree of dark furrows. This factor was described in Part I. p. 82, as an inhibitory factor for gold, and figures were given in Table III. p. 81, showing a *3 : 1* ratio of *green : gold* due to this segregation. The so-called green types, in reality various forms of dark furrows, were described as green merely to indicate the absence of gold. The same *3 : 1* ratio for the presence and absence of *I* has been repeated in a very large number of later families, the two groups appearing, in all cases, being corresponding types of dark furrows and gold respectively.

Where the golds are splitting into different groups, due to the segregation of *G* or one of the modifying factors, the dark furrows show the same groups. An example of this is given in Table III. showing the segregation occurring in the *G g I i* type, where the usual three groups appear in both golds and furrows.

The first two families are $F_2$'s of a cross between dark furrows, *G G I I*, and *ripening gold*, *g g i i*; the others are from plants of *G g I i* constitution extracted from a more complicated cross.

TABLE III.

*Segregation of* G g I i.

| Origin of parent | Ref. No. | Furrows | | | Gold | | |
|---|---|---|---|---|---|---|---|
| | | Dark G G I | Medium G g I | Ripening g g I | Dark G G i | Medium G g i | Ripening g g i |
| $F_1$, G G I I × g g i i .. | 2569 | 143 | 325 | 151 | 54 | 110 | 58 |
| | 2573 | 237 | 482 | 267 | 81 | 170 | 74 |
| Cross No. 1236 N .. | 1763 N | 188 | 385 | 193 | 80 | 126 | 75 |
| Medium furrows from | 2237 N | 126 | 230 | 126 | 43 | 86 | 50 |
| No. 1763 N .. | 2240 N | 80 | 165 | 78 | 24 | 49 | 26 |
| | 2244 N | 75 | 168 | 86 | 27 | 59 | 30 |
| Miscellaneous .. | 3 lots | 215 | 412 | 237 | 63 | 166 | 67 |
| TOTAL .. | | 1,064 | 2,167 | 1,138 | 372 | 766 | 380 |
| *3 : 6 : 3 : 1 : 2 : 1* .. | | *1,104* : | *2,207* : | *1,104* : | *368* : | *736* : | *368* |
| | | | 4,369 | | | 1,518 | |
| *3 : 1* | | | *4,415* | | | *1,472* | |

Counts have been made in a very large number of families showing segregation of *I* and the total figures are as follows :—

| | Dark furrows (various) | Gold (various) |
|---|---|---|
| 120 families .. | 98,541 | 32,126 |
| *Calculated 3 : 1* .. | *98,000* | *32,667* |

*Piebald factor* P

The action of this factor has been described in Part I, pp. 85 and 86, where figures are given, Table VII, showing a simple *3 : 1* ratio of *piebald : self-colour* in both gold and dark furrows. Only one further family giving this type of segregation has been examined; this was the $F_2$ of a cross between *dark gold, G G i i pp*, and *piebald dark furrows, G G I I P P*.

The following figures, showing approximately the *9 : 3 : 3 : 1* ratio expected, were obtained :—

| | Dark furrows | | Gold | |
|---|---|---|---|---|
| | Piebald G I P | Self-colour G I p | Piebald G i P | Self-colour G i p |
| No. 1285 N .. | 969 | 278 | 283 | 97 |
| *9 : 3 : 3 : 1* .. | *915* : | *305* : | *305* : | *102* |

The piebald types are shown in Plate I, figs. 6 and 7.

The effect of the piebald factor on the ripening gold type has not yet been noted.

*The factor* T.

The action of this factor is very similar to that of *P*, since it limits the colouring due to *G*, though to a smaller extent. In homozygous dark golds it produces *tipped gold*, a type in which small green areas appear at the apex and base of the glumes (Plate I, fig. 8). The green areas vary somewhat in size and occasionally the lower one is absent, the base of the grain being entirely gold. In heterozygous golds, where the colour is lighter, the restriction of the gold colour is greater and much less regular, giving a very variable type, *patchy gold* (Plate I, fig. 9).

The restriction of dark furrows is very irregular, the result being a considerable reduction of the pigment, which assumes a granular appearance, and its restriction roughly to the middle part of the grain. The type produced, *granular dark furrows* (Plate I, fig. 10), shows very considerable variation. The reduction of pigment is much greater in the *Gg* type, as with the golds, but it is not possible actually to separate two types corresponding to tipped and patchy golds.

The factor *T* inhibits ripening gold almost entirely, giving *ripening straw* in which the glumes are slightly yellowish in early stages (Plate I, fig. 3), but ripen to ordinary straw-colour (Plate II, fig. 3). Occasionally a few grains show traces of gold in very small patches and there is some indication that this is more common in heterozygotes of the *Tt* type. The golden internode is not affected but persists in the ripening straw type as one of its distinctive e atures.

The results given in Part I, pp. 82–84 and Tables IV–VI, are now easily explained. The original cross that gave the families of Table IV

1. Ripening gold
2. Ripening furrow
3. Ripening straw
4. Dark gold
5. Dark furrows
6. Mottled dark gold

PLATE II.

was obviously of the constitution *G g T t*, and the two families followed up were—

No. 431 *g g T t* giving a simple *3 : 1* ratio of *ripening straw : ripening gold*, Table V.

No. 432 *G g T T* giving a *1 : 2 : 1* ratio of *tipped gold : patchy gold : ripening straw*, Table VI.

In both cases further generations confirmed these results.

A large amount of material arising from various crosses has now been examined and in all cases the above explanation of the behaviour of *T* is in strict accordance with the results. It appears, however, that there may be some other factor producing slight modifications. Thus in some groups the tipped golds are quite distinct, whereas in others they are not easily separable from some of the patchy golds. Similarly in some groups the ripening straws constantly show specks of gold, whereas in others this is very rare.

Below are given the results from two crosses between pure types, and also the summarized results of several generations from certain natural crosses in which the same factors are concerned.

*Tipped gold, G G T T,* × *dark gold, G G t t,* gave *tipped gold* in $F_1$. A simple *3 : 1* ratio of *tipped gold : dark gold* resulted in $F_2$ as follows :—

| | Tipped gold G T | Dark gold G t |
|---|---|---|
| No. 2596 .. | 599 | 184 |
| *Calculated 3 : 1* .. | *587* : | *196* |

*Dark gold, G G t t* × *ripening straw, g g T T,* gave *patchy gold* in $F_1$. Six groups appeared in $F_2$ but patchy and tipped golds were counted together, as also dark and medium golds. The figures for the four main groups separated were as follows :—

| | Gold | | Ripening | |
|---|---|---|---|---|
| | Tipped & patchy G T | Dark & medium G t | Straw g T | Gold g t |
| No. 2581 .. .. | 1.335 | 455 | 443 | 170 |
| *Calculated 9 : 3 : 3 : 1* | *1.351* : | *451* : | *451* : | *150* |

Similar results were given by a natural cross of which the progeny have been followed up in some detail. The $F_1$ appeared as a *patchy gold* plant in a family giving a simple *3 : 1* ratio of ripening straws to ripening golds. This cross, No. 748 N, was obviously of the constitution *G g T t*, as No. 2581 above, since it gave the same groups in $F_2$.

At that time, however, the behaviour was not understood and the groups were not properly separated; thus no numbers can be given for $F_2$. The results given by plants carried forward in $F_3$ and $F_4$ are summarized in Table IV where it will be seen that the various types are behaving according to expectation.

TABLE IV.

*$F_3$ and $F_4$ of No. 748 N.*

| Parent characters | No. of lots | Tipped gold G G T | Patchy gold G g T | Gold G t | Ripening straw g T | Ripening gold g t |
|---|---|---|---|---|---|---|
| Dark gold .. | 9 | .. | .. | pure | .. | .. |
| Medium gold .. | 14 | .. | .. | 9,511 | .. | 3,212 |
| | (*3 : 1*) | .. | .. | *9,542* | .. | *3,181* |
| Ripening gold .. | 21 | .. | .. | .. | .. | pure |
| Ripening straw (all slight gold patches) | 5 | .. | .. | .. | 5,017 | 1,610 |
| | (*3 : 1*) | .. | .. | .. | *4,970* | *1,657* |
| Patchy gold .. | 13 | 6,491 | | 2,016 | 2,183 | 682 |
| | (*9 :3 :3:1*) | *6,805* | | *2,132* | *2,132* | *711* |
| Ditto . | 1 | 650 | 1,323 | | 690 | .. |
| | (*1:2:1*) | *666* | *1,331* | .. | *666* | |
| Tipped gold .. | 1 | pure | .. | .. | .. | .. |
| Ditto . | 5 | 2,768 | .. | 804 | .. | .. |
| | (*3 : 1*) | *2,679* | .. | *893* | .. | .. |

Two crosses, appearing as *granular dark furrows* in a pure ripening gold lot, gave similar results to the above with the added complication of segregation for the factor *I*. The $F_2$'s were not properly separated into groups for counting but the same groups appeared as in Nos. 2581 and 748 N above, together with the corresponding dark furrows types, *viz.*, *granular dark furrows*, *dark furrows*, *granular ripening furrows* and *ripening furrows*.

One family only, No. 1236 N, was followed up. The gold types, where *I* was absent, gave results similar to those of Table IV. The lots showing segregation for *T* are summarized in Table V. There was some difficulty in separating tipped and patchy golds in some of these lots, also in separating the lowest grades of patchy gold from some of the ripening straws showing the [illegible] amount of gold in slight patches.

TABLE V.

*$F_3$ and $F_4$ of No. 1236 N, gold lots.*

| Parent characters | No. of lots | Tipped gold G G T | Patchy gold G g T | Gold G t | Ripening straw g T | Ripening gold g t |
|---|---|---|---|---|---|---|
| Tipped gold .. | 3 *(3 : 1)* | 2,091 *2,064* | .. .. | 675 *691* | .. .. | .. .. |
| Patchy gold .. | 24 *(1 : 2 : 1)* | 3,123 *3,048* | 6,018 *6,095* | .. .. | 3,050 *3,048* | .. .. |
| Ditto .. | 13 *(9 : 3 : 3 :1)* | 4,625 *4,621* | | 1,389 *1,540* | 1,680 *1,540* | 522 *513* |

Of dark furrows types the majority that were carried on were of the medium dark furrows type and some of their results have already been given in Tables II and III.

Only eight granular furrows plants were carried on and these gave five types of segregation in $F_3$, as shown by Table VI.

TABLE VI.

*$F_3$ of No. 1236 N, dark furrows lots.*

| Parents | No. of lots | Granular dark furrows GTI | Dark furrows GtI | Granular ripening furrows gTI | Ripening furrows gtI | Tipped gold GGTi | Gold Gti | Ripening straw gTi | Ripening gold gti |
|---|---|---|---|---|---|---|---|---|---|
| Granular ripening furrows . | 1 *(9 : 3 : 3: 1)* | .. .. | .. .. | 629 *607* | 195 *202* | .. .. | .. .. | 188 *202* | 68 *67* |
| Granular dark furrows .. | 1 *(9:3:3:1)* | 632 *621* | 217 *207* | 178 *207* | 78 *69* | .. .. | .. .. | .. .. | .. .. |
| Ditto .. | 1 *(3 : 1)* | 483 *489* | 169 *163* | .. .. | .. .. | .. .. | .. .. | .. .. | .. .. |
| Ditto .. | 4 *(3 : 1)* | 3,803 *3,837* | .. .. | .. .. | .. .. | 1,313 *1,279* | .. .. | .. .. | .. .. |
| Ditto .. | 1 *(9:3:3:1)* | 505 *517* | 156 *172* | .. .. | .. .. | 176 *172* | 82 *57* | .. .. | .. .. |

Several other natural crosses have been found in which the factors *T* and *I* were concerned. Some of these, *granular dark furrows* appearing in a pure tipped gold type, were carried on and gave the results shown in Table VII. Some of the figures are not as near as could be desired to expectation but there is no doubt that they represent the ratios noted.

TABLE VII.

*Segregation of* G G T t I i.

| Origin of parent | Ref. No. | Granular dark furrows G G T I | Dark furrows G G t I | Tipped gold G G T i | Dark gold G G t i |
|---|---|---|---|---|---|
| | 1272 | 846 | 305 | 281 | 103 |
| Natural crosses .. .. | 1275 N | 2,945 | 775 | 838 | 264 |
| | 2 lots | 3,393 | 1,022 | 957 | 360 |
| No. 1272 F. ... .. | 4 lots | 2,660 | 898 | 824 | 270 |
| No. 1275 N F. .. ... | 4 lots | 2,370 | 793 | 874 | 234 |
| | Total | 12,414 | 3,793 | 3,774 | 1,231 |
| | (9:3:3:1) | *11,932* | *3,977* | *3,977* | *1,325* |
| No. 1272 $F_2$ .. .. | 3 lots | 2,466 | .. | 889 | .. |
| No. 1275 N F .. .. | 1 lot | 1,003 | .. | 322 | .. |
| | Total | 3,469 | .. | 1,211 | .. |
| | (3 : 1) | *3,510* | .. | *1,170* | .. |
| No. 1272 $F_2$ .. .. | 2 lots | 1,599 | 592 | .. | .. |
| No. 1275 N $F_2$ .. .. | 3 lots | 2,951 | 733 | .. | .. |
| | Total | 4,550 | 1,325 | .. | .. |
| | (3 : 1) | *4,606* | *1,469* | .. | .. |

*Mottling.*

On several occasions it was noted that certain families derived from natural crosses, splitting for some type of gold or dark furrows colouring, showed a number of plants with *mottled* grain. At first this was put down to

some extraneous cause such as damage by insects or discolouration due to the grain coming in contact with water. It was found, however, that when such plants were carried forward they bred true to this character. The mottling is not seen till the grain is practically ripe; irregular light coloured areas then appear scattered over the grain and give it a distinctly moth-eaten appearance (Plate II, fig. 6).

The inheritance of this character has not yet been worked out from crosses of the pure mottled types but, from the results of two $F_2$ families in which this type was present, it appears to be simply recessive to even-colouring. In the two families concerned six groups occurred, *viz.*, dark, medium and ripening for both gold and furrows. In all groups both *even* and *mottled* occurred in about the same proportion, the total figures showing a *3 : 1* ratio as below :—

| | | | Even | Mottled |
|---|---|---|---|---|
| No. 2569 | .. | .. | 611 | 230 |
| „ 2573 | .. | .. | 981 | 330 |
| Total | .. | .. | 1,592 | 560 |
| *3 : 1* | .. | .. | *1,614* | *: 538* |

Further work on crosses between pure types is necessary to confirm these results but, provisionally, an even-colouring factor *E* may be held responsible for the prevention of mottling.

### 2. Shape of grain.

One of the most striking features of cultivated rice is the enormous variation shown by different varieties in the size and shape of the grain. There must be a large number of factors concerned in this variation and their analysis is likely to prove a matter of some difficulty. Generally speaking, as is very common in such cases, a cross between widely different types gives an $F_1$ somewhere intermediate and an $F_2$ comprising a complicated series of overlapping types that result in a more or less continuous variation between widely different extremes.

In two cases, however, single-factor variations have been found. One of these, connected with a dwarf habit, is described later. The other, with which the present description is concerned, is closely connected with the factor *G* that has been dealt with above.

It will be seen from Plate I that the *ripening gold* and *ripening furrows* types, figs. 1 and 4, are distinctly long and narrow, *fine*, compared with the *dark gold* and *dark furrows* types, figs. 2 and 5, that are shorter and broader, *coarse*. This distinction has been noted in all the varieties so far seen that show these colourings. In other words *G G* varieties are *coarse* and *g g*

varieties are *fine*. The distinction is more a matter of the relation between length and breadth of the grain than of absolute measurements, though very commonly *G G* varieties are both shorter and broader than *g g* varieties.

Crosses between the two types give an intermediate $F_1$ and an $F_2$ comprising three groups—*coarse G G : intermediate G g : fine g g* in a *1 : 2 : 1* ratio.

The connection was first noted definitely in a family, No. 1247 N, giving a *3 : 1* ratio of *dark and medium gold : ripening gold*. Grain measurements were made for each plant and the averages for the two groups were as follows :—

| | No. of plants | Length mm. | Breadth mm. | Length / Breadth |
|---|---|---|---|---|
| Dark and medium gold | 1182 | 8·45 | 3·00 | 2·8 |
| Ripening gold | 378 | 8·85 | 2·75 | 3·2 |

In all cases, both here and in later figures, the *grain* measured was the ordinary grain of *paddy* that breaks off on threshing. This comprises the rice grain enclosed in the inner glumes, with the receptacle and outer glumes attached at the base (Plate III, figs. 1–6). It was found that the measurement of three of the end grains from a well-developed panicle was sufficiently accurate for each plant and, except where otherwise stated, the figures that follow are based on such measurements.

Further families from the above lot confirmed these results : pure dark golds were coarse, pure ripening golds were fine, and splitting lots gave three groups—coarse dark gold, intermediate medium gold and fine ripening gold. The averages of several pure lots are shown in Table VIII compared with one of the splitting lots. The average of a number of natural crosses, occurring as medium golds in the pure ripening gold lots, is also shown.

TABLE VIII.

*Length and breadth of grain and factor* G.

| Ref. No. | Character of parent | Dark gold G G | | Medium gold G g | | Ripening gold g g | |
|---|---|---|---|---|---|---|---|
| | | L. | B. | L. | B. | L. | B. |
| 1794 N | Dark gold | 8·3 | 3·0 | .. | .. | .. | .. |
| 1795 N | do. | 8·3 | 2·9 | .. | .. | .. | .. |
| 1796 N | do. | 7·8 | 2·9 | .. | .. | .. | .. |
| 1789 N | Ripening gold | .. | .. | .. | .. | 8·8 | 2·6 |
| 1790 N | do. | .. | .. | .. | .. | 8·9 | 2·6 |
| 1791 N | do. | .. | .. | .. | .. | 9·0 | 2·7 |
| 1792 N | do. | .. | .. | .. | .. | 8·9 | 2·7 |
| 1800 N | Medium gold | 8·4 | 3·0 | 8·7 | 2·9 | 9·1 | 2·7 |
| [illegible] | 536 plants | .. | .. | 8·6 | 2·9 | .. | .. |

N.B. *Measurements are in millimetres.*

Since this connection was first noted it has been found to occur constantly in all families segregating for *G*, irrespective of whether the character concerned was dark gold, dark furrows, or both together. In some of the families of which results have been recorded it appears that other factors also have been concerned in the determination of size and, to some extent, shape. Thus the measurements of different families of the same original cross show distinct variations. Conditions of growth undoubtedly affect the size of grain, and possibly also the shape to some extent. This increases the difficulties met with in dealing with such characters; thus one season's measurements cannot be compared directly with those of another. Some of the differences met with, however, are too large and too various to admit of this as the whole explanation.

This will be seen from Table IX where the results are given of six families, all from the same original cross and splitting in the same manner. They were grown side by side under uniform treatment. The average length and breadth of grain is given for each group, together with the value L/B. It will be seen that the variation from family to family is considerable, though the usual connection between *G* and *shape* still holds for any one family.

TABLE IX.

| Ref. No. | Dark furrows G G | | | Medium furrows G g | | | Ripening furrows g g | | |
|---|---|---|---|---|---|---|---|---|---|
| | L. | B. | L/B. | L. | B. | L/B. | L. | B. | L/B. |
| 2223 N .. | 8·4 | 3·0 | **2·8** | 8·5 | 2·9 | **3·0** | 8·9 | 2·6 | **3·4** |
| 2225 N .. | 8·2 | 2·8 | **2·9** | 8·4 | 2·7 | **3·1** | 8·5 | 2·4 | **3·5** |
| 2229 N .. | 8·4 | 2·9 | **2·9** | 8·6 | 2·8 | **3·1** | 9·0 | 2·5 | **3·6** |
| 2230 N .. | 8·5 | 2·9 | **2·9** | 8·7 | 2·7 | **3·2** | 9·2 | 2·5 | **3·7** |
| 2236 N .. | 8·6 | 2·6 | **3·3** | 8·8 | 2·6 | **3·4** | 8·9 | 2·1 | **4·2** |
| 2241 N .. | 8·4 | 2·6 | **3·2** | 8·4 | 2·5 | **3·4** | 8·5 | 2·3 | **3·7** |

N.B. *Measurements are in millimetres.*

Several crosses between pure types have now been made for further exact work. One of these, No. 2584, *dark gold* × *ripening gold*, has given the results shown in Table X. For the parents and $F_1$ 100 grains each were measured; in $F_2$ 10 grains were measured for each of 100 plants in each group. The table shows the range of variation in length, breadth and length ÷ breadth of each group in $F_2$, together with the averages.

TABLE X.

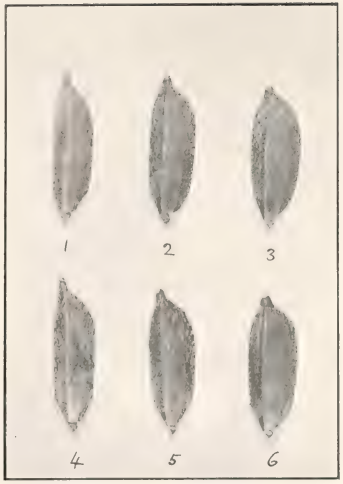
*Grain measurements of No. 2584, $F_2$.*

Dark gold × Ripening gold.

| Length mm. | Number of plants | | | Length / Breadth | Number of plants | | |
|---|---|---|---|---|---|---|---|
| | Dark gold | Medium gold | Ripening gold | | Dark gold | Medium gold | Ripening gold |
| 8·2 | 13 | 2 | .. | 3·0 | 22 | 1 | .. |
| 8·4 | 43 | 13 | .. | 3·2 | 67 | 24 | .. |
| 8·6 | 32 | 40 | 2 | 3·4 | 11 | 62 | .. |
| 8·8 | 11 | 36 | 17 | 3·6 | .. | 11 | 7 |
| 9·0 | 1 | 8 | 39 | 3·8 | .. | 2 | 42 |
| 9·2 | .. | 1 | 33 | 4·0 | .. | .. | 33 |
| 9·4 | .. | .. | 8 | 4·2 | .. | .. | 16 |
| 9·6 | .. | .. | 1 | 4·4 | .. | .. | 2 |
| Average length | 8·43 | 8·63 | 9·10 | Average L/B | 3·14 | 3·34 | 3·88 |
| Breadth mm. | | | | | | | |
| 2·1 | .. | .. | 1 | *Averages for parents and $F_1$.* | | | |
| 2·2 | .. | .. | 17 | | | | |
| 2·3 | .. | .. | 39 | | Dark gold parent | $F_1$ | Ripening gold parent |
| 2·4 | .. | 3 | 40 | | | | |
| 2·5 | .. | 24 | 3 | | | | |
| 2·6 | 18 | 30 | .. | | | | |
| 2·7 | 67 | 23 | .. | | | | |
| 2·8 | 15 | .. | .. | | | | |
| | — | | | Length | 8·30 | 8·72 | 8·75 |
| Average breadth | 2·70 | 2·59 | 2·33 | Breadth | 2·75 | 2·60 | 2·27 |
| | | | | L/B | 3·00 | 3·36 | 3·85 |

It will be seen that the homozygous groups in $F_2$ are quite distinct in shape ; thus, whilst there is some overlapping in length, the groups are quite separate as regards breadth and length ÷ breadth. They do not reproduce very exactly the measurements of the two parents. By an oversight only the actual parent plants of the cross were measured. Had the average of a number of plants of each parental type been taken, it is possible that a closer approximation would have resulted. This point will probably be settled in future generations.

In Plate III, figs. 1–6, photographs are given of single grains from the two parents, $F_1$ and the three groups of $F_2$ of the above cross. The grains were selected so that each corresponds in its measurements with the average of the group from which it was taken.




*Grain shape.* Cross No. 2584.

1. Parent, tapering gold, *fine*.
2. $F_1$ medium gold, *intermediate*.
3. Parent, dark gold, *coarse*.
4. $F_2$ tapering gold, *fine*.
5. $F_2$ medium gold, *intermediate*.
6. $F_2$ dark gold, *coarse*.

*Grain development*

7. Gold rice, *thin*.
8. Red rice, *plump*.

From No. 2573, $F_2$.

PLATE III.

A further point of interest, and one of considerable economic importance, is that the *weight* of the grain varies with its *shape*, the coarser types being heavier. This has been recorded in several families of which one, No. 2584, for which measurements are given in Table X, gave the following figures :—

| | Weight of 100 grains in grammes | | |
|---|---|---|---|
| | Dark gold | Medium gold | Ripening gold |
| Dark gold parent .. | 2·145 | .. | .. |
| Ripening gold parent . | .. | .. | 1·755 |
| $F_1$ .. | .. | 2·050 | .. |
| $F_2$ .. | 2·144 | 2·075 | 1·910 |

The figures for $F_2$ represent the averages of 100 plants in each group ; for $F_1$ and the parents only the single plants concerned were weighed.

It is not possible at present to give a definite interpretation of the connection between grain shape and the factor *G*. That a very close connection exists is obvious from the results given. Coarseness may be due to a separate factor closely linked with *G*, or, on the other hand, the factor *G* itself may be the determining factor. Further work, including a search for cross-over types, is necessary before a definite statement can be made.

### 3. A dwarf habit.

Reference has already been made to a single-factor variation in grain-shape that is connected with a *dwarf* habit. The variety that introduced this habit is strikingly different from ordinary varieties in many important points and is the only one of its kind that has been seen. It was obtained, through the courtesy of Mr. McKerral, Deputy Director of Agriculture, Lower Burma, from the Government Agricultural Station, Hmawbi, Burma.

The plant is shortened and thickened in all its parts and forms a very stiff erect clump. The leaf is coarse and rough, much broader than that of any ordinary variety and quite erect. The panicle is very compact, cigar-shaped and erect, due to its short stiff branches being closely pressed together. The grain is short and rounded.

This dwarf variety, E. B. 304, has been grown for several seasons at Coimbatore and in one of its generations a natural cross appeared. This cross was normal in every respect and showed no trace of the dwarf characters described above. In $F_2$ the whole of the dwarf characters segregated together

and a simple *3 : 1* ratio of *normal : dwarf* was the result, the actual numbers being *1248 : 391*. The dwarfs were absolutely distinct from the normals and, apart from a slight increase in vigour, were identical with the dwarf parent in all its peculiarities. The normals were entirely normal and showed no trace of any of the dwarf characters. Plate IV shows photographs of the two types appearing in $F_2$.

It is obvious that a single factor is concerned in spite of the great differences in a number of parts of the plant.

Certain colour characters and a glutinous rice character introduced into the cross showed the male parent to be a type, E. B. 303, that was growing alongside the dwarf variety in the season when the cross occurred. It is possible, therefore, in giving certain measurements for $F_2$, to compare these with the corresponding measurements of both parents.

Table XI shows the range of variation in height of the normal and dwarf groups of $F_2$ together with that of a certain number of plants of both parents. The height measurement was taken from ground level to the top of the heads gathered together in a bunch.

TABLE XI.

*Segregation for height in $F_2$ No. 2666 N.*

Normal × Dwarf.

| Height in inches | Number of plants | | | |
|---|---|---|---|---|
| | $F_2$ | | Parents | |
| | Normal | Dwarf | E. B. 303 normal | E. B. 304 dwarf |
| 26 | .. | 14 | .. | 10 |
| 30 | .. | 166 | .. | 30 |
| 34 | .. | 186 | .. | .. |
| 38 | .. | 25 | .. | .. |
| 42 | 10 | .. | 5 | .. |
| 46 | 165 | .. | 26 | .. |
| 50 | 533 | .. | 54 | .. |
| 54 | 429 | .. | 42 | .. |
| 58 | 106 | .. | 7 | .. |
| 62 | 5 | .. | .. | .. |
| Average height | 50·5″ | 31·2″ | 49·7″ | 27·9″ |

The figures show the very distinct nature of the segregation, the shortest of the normal group being taller than the tallest dwarfs.

Normal. Dwarf. Normal. Dwarf.

FROM No. 2666. F.

PLATE IV.

Several other measurements were made, including length and breadth of leaf and of grain. The leaf below the flag on three good tillers was measured and the average taken for each plant. There was no overlapping of the two groups as regards breadth of leaf, all the dwarfs being broader than the broadest normal. In length there was some overlapping but the averages for the dwarf and normal groups showed considerable difference. In grain-measurements there was no appreciable difference in breadth but a large difference, with no overlapping, in length. The figures below show the averages for the two groups, together with the parents, of the three measurements showing the greatest differences.

| | $F_2$ | | Parents | |
|---|---|---|---|---|
| | Normal | Dwarf | Normal | Dwarf |
| Length of leaf, cm. .. | 46·1 | 34·6 | 45·7 | 38·1 |
| Breadth .. .. .. | 1·11 | 1·70 | 1·11 | 1·74 |
| Length of grain, mm. .. | 9·77 | 6·50 | 9·28 | 6·36 |

Other crosses with the dwarf type have now been made for further verification with exact measurements.

## 4. Rice colour.

### *Red rice.*

It has already been shown, Part I, p. 100, that in many cases *red rice* is simply dominant to *white* giving a *3 : 1* ratio in $F_2$.

Mention was also made, p. 103, of a family, No. 617 N, that had given a *9 : 7* ratio of *red : white*, followed by a series of varying ratios in a later generation. No explanation of these varying ratios has yet been discovered, though two further generations, comprising a large number of families, have been grown. It appears, however, that at least two factors are concerned. Thus all lots from a family giving approximately a *3 : 1* ratio gave ratios ranging round *3 : 1* in the next generation, whereas lots from families giving a *9 : 7* ratio gave a wide range of ratios varying from *9 : 3·3* to *9 : 11*. Further investigation into the possible causes of such varying ratios is necessary before any explanation can be given.

*Red rice, grey-brown rice and anthocyan pigmentation.*

The relation between *red* and *grey-brown* rice was considered in Part I, p. 101, and later results, with their probable explanation, were given in a postscript. It was shown that, in the families there concerned, the *red rice* colour only developed in plants with *purple pigmentation*, its place being taken by *grey-brown* in *unpigmented* plants. It was suggested that the pigmentation factor concerned was necessary, in addition to a red rice factor, for the production of red rice, and that in its absence the red rice factor produced only grey-brown. The existence of unpigmented varieties with red rice was explained on the assumption that the pigmentation factor lacking in such varieties was different from that lacking in the families under consideration. This theory has now been confirmed by the results of certain crosses.

It has already been shown, Part I, p. 88, that the presence of two factors is necessary for the production of purple (anthocyan) pigmentation. These factors are denoted by *A* and *N*, the red rice factor by *R*, in the description that follows.

Taking *A* as the pigmentation factor connected with rice colour, *A R* will be *red*, *a R* will be *grey-brown*. Thus the *9 : 3 : 3 : 1* ratio, made up of *3 : 1*, *red : white*, in the pigmented group and *3 : 1*, *grey-brown : white*, in the unpigmented group, as shown by Table XXI in the postcript of Part I, is the expected result from a parent of the constitution *A a N N R r*. The simple *3 : 1* ratio of *pigmented, red : unpigmented, grey-brown* is the result from *A a N N R R*.

An *unpigmented, grey-brown, a a N N R R*, from the latter type of segregation, was crossed with a *pigmented, white* variety, *A A N N r r*, and gave a *pigmented, red* F$_1$, *A a N N R r*. In F$_2$ the expected *9 : 3 : 3 : 1* ratio resulted, four families giving the following figures :—

| | Pigmented | | Unpigmented | |
|---|---|---|---|---|
| | Red<br>A N R | White<br>A N r | Grey-brown<br>a N R | White<br>a N r |
| No. 1512 I-4-2 .. | 1,785 | 602 | 587 | 184 |
| ,, 1 .. | 1,776 | 567 | 581 | 187 |

A more interesting cross was between the same *unpigmented, grey-brown a a N N R R*, and an *unpigmented, white* of the constitution

*A A n n r r*. The latter was selected from a family that had given unpigmented plants with red rice, thus showing that the pigmentation factor lacking must be *N*. F was *pigmented, red*, as expected from the constitution *A a N n R r*. In F five groups appeared as shown below. The figures are not as near as could be desired to expectation but there is no doubt that they represent the ratio shown.

| | Pigmented. | | Unpigmented | | |
|---|---|---|---|---|---|
| | Red | White | Red | Grey-brown | White |
| | A N R | A N r | A n R | a $\left(\begin{smallmatrix} N \\ n \end{smallmatrix}\right)$ R | $\left(\begin{smallmatrix} A\ n \\ a\ N \\ a\ n \end{smallmatrix}\right)$ r |
| No. 2508 .. | 283 | 119 | 108 | 129 | 85 |
| 27 | 80 | 102 | 102 | 138 | 76 |

These results definitely confirm the above theory regarding the nature of grey-brown rice and also afford additional confirmation of the existence of two factors necessary for the production of anthocyan pigmentation.

*Red rice and golden rice.*

An account has already been given above of the factor *I* which inhibits gold in the internode and changes any form of gold in the glumes to a corresponding form of dark furrows. It appears that this factor also is necessary for the production of red rice by the factor *R*. In the absence of *I*, that is to say, in all types with *golden glumes or internode*, the factor *R* produces *golden rice*. All *red-riced* plants so far seen have shown some form of *dark furrows* colouring in the glumes. The same applies to the various shades of light reddish rice that are common. This colouring is only produced in dark furrows types ; in golden types it is replaced by a yellowish or cream colour.

At the time of ripening golden rice is very easily distinguishable from red, as shown in Plate V, figs. 1 and 2. After keeping for some time much of the yellow colour disappears and the rice becomes duller and more brown. At this stage, if seen casually, it might be mistaken for red though the two are still separable with certainty.

Golden rice has occurred in a large number of families showing segregation for *I* in the presence of *R*. In all cases the red rice of the dark furrows group has been replaced by golden rice in the gold-glumed group. An example of this is seen in the results from a cross between *dark furrows, red rice* and

*typewing gold, yellowish rice.* $F_1$ was *dark furrows, red rice* and two $F_2$ families gave the following results :—

| | *Furrows* types | | *Gold* types | |
|---|---|---|---|---|
| | Red | Slightly reddish | Gold | Yellowish |
| Nos. 2573 & 2569 | 1 214 | 391 | 401 | 146 |
| *9 : 3 : 3 : 1* .. | *1,210* | *403* | *403* | *134* |

From natural crosses giving similar results to the above several families, raised from red-riced $F_2$ plants, have given a simple *3 : 1* ratio of *dark furrows red rice : gold glumes, gold rice.*

*Golden rice and undeveloped grain.*

In all families in which golden rice has occurred the grain of this type has been very poorly developed. Setting appears to be normal but the rice grain is never properly filled out and frequently shrivels some time before it is fully grown. Other types of rice occurring in the same family are always quite normally developed. In Plate III are given photographs of a few typical grains of gold and red rice, from No. 2573 $F_2$, showing the poor development of the gold rice as compared with the red.

Grain weighments have been made in this family and the gold rice falls considerably below other groups. Weighments were made of the unhusked *paddy* grain as this was required for seed purposes later. The family was splitting for the factor *G* and this introduced a complication owing to the connection between this factor and grain shape and weight that has already been noticed. For this reason average weights are given for each of the twelve groups appearing. For each group 10 plants, 100 grains each, were weighed, except where otherwise noted. The weights in grammes of 100 grains were as follows :—

| | *Furrows* types | | *Gold* types | |
|---|---|---|---|---|
| | Red<br>R 1 | Sl. reddish<br>r 1 | Gold<br>R 1 | Yellowish<br>r 1 |
| Coarse. *G G* . | 2·250 | 2·219 | 1·695 | 2·193 * |
| Medium. *G g* . | 2·182 | 2·142 | 1·721 | 2·113 |
| Fine. *g g* | 1·974 | 1·947 | 1·556 | 1·868 † |
| Average .. | 2·135 | 2·093 | 1·657 | 2·058 |

* *6 plants only.* † *13 plants only.*

The falling-off in weight of all three gold rice groups, as compared with the others, is very obvious. No explanation of this behaviour can be offered at present. In both parents the grain was perfectly normally developed.

*Purple rice.*

In a few, rather uncommon, varieties the colour of the rice is very dark purple. There is some variation in the depth of colour in different varieties, some being almost black (Plate V, fig. 3), and others rather lighter, with a reddish or brownish tinge on one side (Plate V, fig. 4). All the varieties seen with purple rice have been glutinous types, mostly from Burma. There is, however, no genetic connection between the purple colour and glutinous rice.

Purple rice is dominant to white and gives a simple *3 : 1* ratio of *purple : white* in $F_2$. The total figures for a large number of families are given below. The purples are somewhat in excess but the figures undoubtedly represent a *3 : 1* ratio.

| | *Purple rice.* | *White rice.* |
|---|---|---|
| 54 families .. .. | 17,850 | 5,557 |
| *Calculated 3 : 1* .. | 17,555 | 5,852 |

The main purple rice character is obviously due to a single factor. It appears, however, that there are other factors affecting the depth of the purple colouring.

The $F_1$ of the darkest type of *purple* × *white*, though showing some variation, is always lighter in colour than the purple parent, especially on the dorsal side at the lower end of the grain, and shows a distinct brownish tinge (Plate V, fig. 5). In $F_2$ the purple group shows considerable variation, ranging from dark purple to a type where the purple is very considerably reduced and a definite brownish tinge appears. It is quite impossible to separate distinct groups as the variation is practically continuous.

In $F_3$ the darkest types breed true for purple though the very dark colour of the purple parent is rarely reproduced, the majority being rather lighter and slightly brownish, resembling the lighter purple varieties mentioned above. The lighter types of $F_2$ purples are mostly heterozygous, showing the same type of segregation as occurs in $F_2$, though some distinctly light types have been found to breed true.

There is no connection between the main purple rice factor ***P*** and the red rice factor ***R*** since white rice arises in $F_2$ from *purple* × *red*. $F_1$ is *purple red* since the red colour shows through where the purple is reduced (Plate V,

fig. 6). In $F_2$ a 12 : 3 : 1 ratio of *purple : red : white* is obtained as shown by the following figures:

| | Purple P R - P r | Red p R | White p r |
|---|---|---|---|
| 22 families | 1540 | 1,215 | 149 |
| Calculated 12 : 3 : 1 | 1605 | 1176 | 98 |

The purple group is a very mixed lot for the same variation exists as described for $F_2$ of the purple white cross and, in addition, various degrees of purple-red appear. Some of the latter, where the purple is reduced to the greatest extent, nearly approach ordinary red though they are separable in well-developed grain.

Purple $F_2$ plants give four types of family in $F_3$—*pure purples*, 1 : 1 ratios of *purple : white*, 3 : 1 ratios of *purple : red*, and the same as $F_2$ again. Some of the pure purples show considerable reduction of the purple colouring, as noted above in the purple × white lots, and in such cases the *P P R R* type appears as purple-red like the $F_1$ *P p R r*.

It may be noted here that the factor *P* falls into the same linkage group as *L*, *G*, *S* and *A*, the factors responsible for purple colouring in the internode, glumes, stigma and axil, as described in Part I, pp. 91–97. Several other factors have also been found to fall into the same group and their relations will form the subject of a future paper.

### *Purple and brown rice.*

Just as the pigmentation factor *A* is necessary in the production of red rice so also it is necessary in the production of purple rice. In its absence the factor *P* produces *brown* rice (Plate V, fig. 7), corresponding to the *grey-brown* rice of the factor *R* (fig. 8).

This behaviour has not been worked out in detail, as in the case of grey-brown rice, but is sufficiently evident from the results of a natural cross that proved to be of the constitution *P p R r A a N n*. $F_2$ gave a 9 : 7 ratio of *pigmented : unpigmented*. The former group comprised *purple*, *red* and *white* and the same three types, together with *brown* and *grey-brown*, occurred in the unpigmented group.

Accurate counts were not made as there was some difficulty in separating the rice groups with certainty. The same difficulty was experienced in the more complicated families in $F_3$. The degree of ripeness affects the rice colour considerably; also, apparently, the rapidity with which maturation takes place has some effect on the degree of development of the colour. For this reason

1

2

3

4

5

6

7

8

RICE COLOURS.

1. Gold
2. Red
3. Dark purple
4. Light purple
5. F$_2$ Purple × white
6. F$_2$ Purple × red
7. Brown
8. Grey brown.

PLATE V.

it is a matter of some difficulty to obtain reliable figures where a number of different types of rice colour are concerned.

Sixty $F_3$ families were raised from various types of $F_2$ plants* of the above cross and the results were in complete agreement with expectation so far as the types of segregation were concerned. The tables that follow show the types of segregation obtained from all the $F_2$ plants possessing the factor *P* that were carried on as parents.

In Table XII, which comprises the pigmented, purple rice parents, the types appearing in the different families are shown by a + sign under the respective headings.

TABLE XII.

*Pigmented, purple rice parents.*

| Constitution | No. of lots | PIGMENTED | | | UNPIGMENTED | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Purple P A N | Red p R A N | White p r A N | Purple P A n | Brown P a | Red p R A n | Grey-brown p R a | White p r |
| | | | 9 | | | | 7 | | |
| P p R r A a N n .. | 7 | + | + | + | + | + | + | + | + |
| P p R R A a N n .. | 2 | + | + | | + | + | + | + | |
| P p r r A a N n .. | 2 | + | | + | + | + | | | + |
| P P . . A a N n .. | 4 | + | | | + | + | | | |
| | | | 3 | | | | 1 | | |
| P p R r A a N N .. | 3 | + | + | + | | + | | + | + |
| P p r r A a N N .. | 2 | + | | + | | + | | | + |
| P p R r A A N n .. | 1 | + | + | + | + | | + | | + |
| P p R R A A N n .. | 2 | + | + | | + | | + | | |
| P P . . A A N n .. | 1 | + | | | + | | | | |
| | | | Pure | | | | | | |
| P p R r A A N N .. | 1 | + | + | + | | | | | |
| P P . . A A N N .. | 5 | + | | | | | | | |

In Table XIII families from unpigmented parents, both purple and brown rice, are shown in the same way.

* Selected to cover the range of variation but with no reference to their proportions in $F_2$.

TABLE XIII.

*Unpigmented parents.*

| Parent | Constitution | UNPIGMENTED | | | | | |
|---|---|---|---|---|---|---|---|
| | | No. of lots | Purple P A n | Brown P a | Red p R A n | Grey-brown p R a | White p r |
| Purple .. | P P . . A A n n | 2 | + | | | | |
| Do. .. | P P . . A a n n | 2 | + | + | | | |
| Do. .. | P p R R A A n n | 1 | + | | + | | |
| Do. .. | P p R R A a n n | 2 | + | + | + | + | |
| Do. .. | P p R r A a n n | 2 | + | + | + | + | + |
| Brown .. | P p R r a a . . | 4 | | + | | + | + |
| Do. .. | P p R R a a . . | 1 | | + | | + | |
| Do. .. | P P . . a a . . | 1 | | + | | | |

The purple rice character does not appear to be affected by the factor *I* as is the red rice character. Thus in one $F_2$ family segregating for *I* in the presence of *P* the plants with golden glumes showed the same purple rice colour as appeared in plants with dark furrows.

COIMBATORE :
16*th July*, 1921.